A REPORT ON

SPARTINA ANGLICA CONTROL
GRANGE-OVER-SANDS
1998-1999

FOR

SOUTH LAKELAND
DISTRICT COUNCIL

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SUMMARY

Concern has been expressed about the continued spread of the grass Spartina anglica *across the foreshore at Grange-over-Sands. The grass has begun to develop a continuous cover and it is felt that there is consequent loss of visual amenity. Grange Town Council has requested that the local planning authority, South Lakeland District Council, takes some action. The foreshore at Grange lies within a site of national and international importance for its wildlife interest, and carries statutory designation in recognition of this.*

Consent has been given to attempt control of the Spartina *by a method known as rotoburial. Two ranks of 100m x 30m plots have been marked on the shore, with half scheduled for treatment and half to be used as a baseline against which to measure any change. Rotoburial of some of the plots was carried out in September 1998 and April 1999. In addition two plots were managed by hand pulling and digging.*

This report describes and discusses the various aspects of the monitoring carried out. Sediment sample were collected from treated and untreated plots in April 1998 and May 1999. These were stored and later analysed for their physical and chemical properties. Records were also made of plant cover, sediment characteristics and invertebrates. Observations of the variables were also made at other times of the year.

Analysis showed that the sediment is largely comprised of fine sand. Trends in the silt and clay proportions and of chemical content tended to be similar across all samples, regardless of whether treated or untreated. Invertebrate studies indicate that there may be an initial ingress of animals to treated plots but in time the population levels become stable again. Vegetation cover in untreated plots increased from 1998 to 1999. Plants appeared to have been eliminated from the plots which were treated, though it was noted that plants seeded into these plots later in the year.

Rotoburial does not appear to have any adverse impact on invertebrates or on sediment character and chemistry. The treatment seems to eliminate Spartina *cover, at least on a short term basis.*

This report also outlines the background history of Morecambe Bay and its saltmarshes, in order to give some idea of why things are as they are and to attempt to predict what will happen in the future.

The history of land claim has had a profound impact on processes, the most notable impact probably being construction of the railway in the years up to 1857. Land claim is considered to be the cause of the ongoing sediment accretion in Morecambe Bay.

The second key process in the Bay is the migration of the low tide channels of the larger rivers, particularly that of the Kent. The third would be the arrival of Spartina anglica.

/continued →

The work of others on the histories of channel movements and Spartina *is described, complemented by the authors' own observations. Comparisons are made with Southport, where there has also been attempts at the control of* Spartina *on an accreting and prograding amenity beach.*

In the regime of continued accretion and with the present lack of tidal scour it is concluded that, the development of saltmarsh at Grange-over-Sands is inevitable. A limited amount of control is likely to be possible but continued accretion and consequent expansion of saltmarsh area means that control would become increasingly consumptive of resources. The report explains that an area of well-developed saltmarsh at Grange would provide a valuable resource for amenity and for wildlife.

The cyclic movement of the Kent channel from Grange to Silverdale and back again has led to alternating periods of erosion and accretion. With the channel presently towards Silverdale that side of the Bay is currently undergoing episodes of erosion while Grange experiences a period of enhanced accretion. In due course the channel will move back towards Grange and the processes will be reversed. The report points out that saltmarsh development at Grange did commence at the end of the 1980s but was terminated by the appearance of a subsidiary channel which eroded away the saltmarsh and much sediment. Such a subsidiary channel could reappear at any time, regardless of the position of the main channel.

The report also investigates the lobbying for the removal of the training wall of the river Winster. The wall was felt by some people to be the cause of sedimentation along the Grange shoreline. Its subsequent removal has shown this is not the case, the only impact being severe erosion of intertidal sand and mature saltmarsh at Meathop. This report suggests that no further wall should be removed and that reinstatement may be necessary.

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1. INTRODUCTION

1.1 Background to the study

Spartina anglica is a tussock-forming species of grass, also known as Common Cord-grass and often referred simply as “Spartina”. Spartina grows on intertidal muds and sands and is sometimes able to grow at lower levels of the shore than the plant species “traditionally” associated with this habitat.

Spartina has been present in the Grange-Kents Bank section of Morecambe Bay since at least the early 1970s. Its initial appearance caused annoyance and some localised control works were undertaken. In the 1990s there has developed areas of continuous cover of Spartina alongside the promenade at Grange-over-Sands. The changing appearance of the nearshore areas has provoked outcry at the loss of visual amenity, with the matter discussed at meetings of Grange Town Council and in the letters and news pages of the local press. It is felt that something should be done about what is variously described as

“virulent and quick spreading (grass)” (*Westmorland Gazette*, 13.03.87)
“this creeping menace” (*Westmorland Gazette*, 30.09.88)
“shore grass menace” (*Grange & District Memorandum*, 14.09.89)
“still threatens to swamp Grange’s picturesque shoreline” (*Westmorland Gazette*, 13.10.89)
“coastal weed threat to Bay” and “spreading in epidemic proportions” (*Visitor*, 21.03.90)
“a green beach is the last thing Grange-over-Sands needs” (*Westmorland Gazette*, 20.02.98)

The shore at Grange lies within a site with statutory recognition as being of national importance for wildlife, the Morecambe Bay Site of Special Scientific Interest (SSSI). It also forms part of a complex of several SSSIs which are now recognised as being of significant importance in an international context.

Thus any actions taken against Spartina at Grange must take into account any obligations held under British and European laws (see, eg, English Nature 1999).

With this in mind, meetings have been held between representatives of Grange Town Council, South Lakeland District Council (SLDC, the local planning authority), and English Nature (the body with statutory responsibility for nature conservation in England). The meetings have also been attended by representatives of statutory bodies such as the National Rivers Authority (NRA) and its successor body the Environment Agency, and by locally based research scientists from the Institute of Terrestrial Ecology (ITE).

Work by English Nature at Lindisfarne in north-east England has suggested that Spartina may be brought under control by using a tractor-mounted rotoburying device. This agricultural machinery is normally used to bury stones in areas used for turf cultivation. At Lindisfarne the rotoburier sends the Spartina to a depth from which it is no longer capable of regeneration.

It was decided to try the Lindisfarne methods on the shore at Grange. Mechanical rotoburying would have the benefit of avoiding the use of organic pesticides which might accumulate in the food chain and result in long term damage to the ecosystem.

SLDC was to be the lead authority in the control work. It would obviously be sensible to undertake some locally based trials before embarking on any potentially highly costly programme. SLDC, English Nature and ITE devised a monitoring scheme. A number of rectangular marked plots would be set out on the foreshore. Half of these plots would be rotoburied and half would be used as "controls".

Though the rotoburying would avoid the use of chemicals there was still potentially a problem with the disturbance to shellfish, worms and other invertebrate animals living in and on the sediments. These invertebrates form the diet of the wildfowl and waders which contribute to the national and international importance of Morecambe Bay. As well as direct disturbance to the animals, disruption of sediment might also result in a change from finer to coarser or vice versa, with possible redistribution of animal populations and communities as a consequence.

Comparisons between rotoburied and control plots would give some indications of whether there may be any adverse effects on the invertebrates.

In addition to the possible impacts on invertebrates and, ultimately, birds, there is the possibility that disturbance to sediments could release buried inorganic or organic material into the wider environment. This material might include plant or animal nutrient material or potentially harmful substances such as heavy metals.

It was decided that sediment samples should be taken from the marked plots. The samples would be analysed for various physical and chemical properties. The visits to collect sediment samples would also give the opportunity to record plant species and cover in the plots, to make notes on surface and sub-surface soil conditions, and to record animals in and on the substrate.

The trial plots were marked out by SLDC during the winter of 1997-98. Each plot is 100 metres in length and 30 metres in width, with the long axis approximately at right angles to the promenade. Plots are pegged at the four corners and at the midpoint of the longer sides. Red pegs are used for the plots to be rotoburied and yellow pegs for the control plots.

The plots are set out in two ranks, with the inner rank running along the base of the promenade from just past the site of the old baths up to Grange station. The outer rank is set a little to the seaward. The curvature of the shoreline and the presence of creeks and a spring-fed pool means that the intervals and overall layout do not follow a precisely geometric pattern.

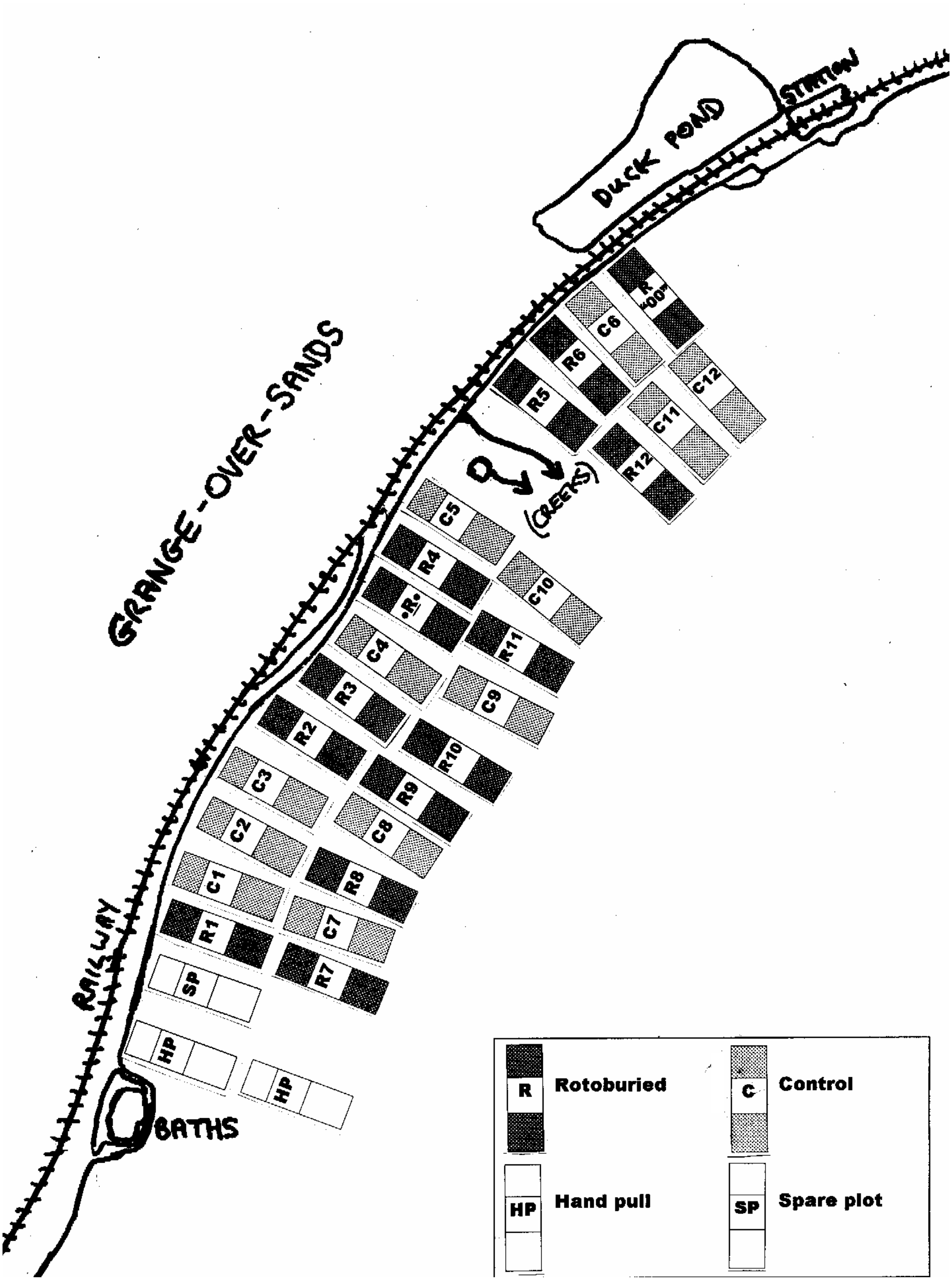
Twenty-seven trial plots were initially pegged out. The inner rank has eight to-be-rotoburieds, six controls, and a "spare" plot. The outer rank has six each of to-be-rotoburieds and control plots.

It was considered that it would be a good idea to involve local people in the work and so two further plots were marked out in the area immediately adjacent to the old baths, with one inshore and one to the seaward. These two plots (referred to as "Hand pulls") would be manually "weeded" by volunteers.

The location and orientation of the trial plots is shown in **Figure 1**.

The rotoburying trials were scheduled to start in the spring of 1998.

Figure 1 Location and orientation of trial plots



("•**R**•" is plot without pegs 1998-99; "**R 00**" is an extra plot.)

1.2 Methods used in the study

The initial sampling of the trial plots was carried out in the latter part of April 1998. Within each plot sampled a 10m x 10m square ("quadrat") was randomly selected. A visual estimate was made of the cover and aggregation of the plant species present in the quadrat, and also of the various types of algae (if present). A sediment core of 8cm diameter and 30cm depth was taken within the quadrat and bagged and labelled. Notes were made on sediment properties and the presence of animals (or their traces) both within the hole temporarily created and across the surface area of the quadrat. The bagged samples were stored in the cold room at ITE Merlewood. Fractions of some of the sediment samples were sieved to see if any invertebrates were present.

The first attempt at rotoburying was undertaken in late April 1998. Unfortunately the tractor became embedded in sediments only a few metres from the promenade and the operation was put on temporary hold.

Work on the Hand pull plots was undertaken on the weekends June 6-7 and July 4-5 1998. One of the participants, John Marshall of Grange-over-Sands, has produced a thorough account of the work done and the most effective means of achieving this (Marshall 1998). The considerable efforts of the volunteers resulted in the clearing of all of the outer plot and 50% of the inner one.

Rotoburying got under way on September 1 1998. This resulted in the complete burial of the two southernmost outer rotoburial plots (R7 & R8) and the burial of 50% of the southernmost inner rotoburial plot (R1) (see **Figure 1** for location of these and other plots mentioned).

Further rotoburying was carried out on April 9 1999. Complete burial was achieved on one outer (R8) and one inner (R3), with also 50% burial of the adjacent inner plot (R2).

The 1999 vegetation and sediment sampling was carried out in the May of that year, obviously after the above sets of treatments. The same sampling methodologies were used as in 1998. The Hand pull plots were not sampled in 1998 but were sampled in 1999. For some plots a second sample of sediment was collected. As in 1998, the 1999 sediment samples were placed in the cold room at ITE Merlewood.

Some of the 1998 and 1999 sediment samples were presented for analysis to the Environmental Chemistry team at ITE Merlewood. In an ideal situation more samples would have been gathered and all samples would have presented for analysis. The cost of chemical and physical analysis is relatively high and the analysis of a larger number of samples would have eaten into the costs available for the remaining elements of the project work.

One of the aims of the analysis was to attempt comparisons with a previous study of the intertidal sediments of Morecambe Bay (Anderson 1972). With this in mind, twenty-six samples were analysed for the following:

Moisture
Loss on ignition (LOI)
Extractable sodium (Na), potassium (K), calcium (Ca) & phosphate (Po_4-P)
Total copper (Cu), lead (Pb), zinc (Zn), cadmium (Cd)
Total nitrogen (N)
Silt, clay, fine sand & coarse sand

The results of the analysis and the methods used are included in Woods *et al* (1999).

Undergraduate students of the University of East London (UEL) have undertaken field work on the foreshore at Grange in the May of 1998 and 1999. The 1998 UEL work produced some interesting results, though their apparent recording of snails found only in south-east England was viewed with some suspicion. It was hoped that the 1999 UEL work could be fitted to the particular needs of our project but it was found that university curricula and regulations meant that the students apparently had to stick to a work plan devised by university staff some time prior to their arrival in north-west England. It has however been possible to incorporate into this report some of the observations made during the 1999 UEL work.

This report also takes into account various other concerns expressed about the foreshore in the Grange area, including the effects of the Winster channel and broader impacts on factors such as wildlife and amenity.

Various persons have been consulted both locally and nationally, and the report also draws on the authors' experience and knowledge of Spartina and the shoreline from other parts of north-west England and elsewhere.

2. RESULTS OF INVESTIGATIONS 1998-99

2.1 Sediment analysis

The results of the analyses are set out in **Table 1**. The data for moisture content and coarse sand have not been included in the table for reasons explained in the sub-sections below.

Any trends suggested by the data are discussed in section **3** of this report.

2.1.1 Physical properties

The sediment samples were found to be largely comprised of fine sand. Coarse sand was present as a trace (<0.5%) in all but one sample (R3 1999), where a figure of 0.6% was recorded. The amount of fine sand is to all intents thus proportional to the overall total (100%) minus the combined totals of silt and clay (see **Table 1**).

The proportion of silt content is greater in the inner plots than in the outers. Both inner and outer plots show a decline in silt content from 1998 to 1999, with the exception of R3, where there was an increase.

Clay generally forms a lower proportion of total sediment content than does silt. The inner plots show a decline in clay content from 1998 to 1999, with the exception of R3, which, as with silt, showed an increase. The outer plots all showed an increase in clay content from 1998 to 1999, in each case causing the proportion of clay to be greater than that of silt.

The Hand pull plots were not sampled in 1998. In 1999 the samples from the inner plot had a relatively high silt to clay ratio; while in the outer plot samples clay and silt proportions were equal.

Loss on ignition (LOI) data showed little variation between 1998 and 1999. In only two plots did the proportion rise or fall by >0.5%, with R2 declining and R3 increasing.

The moisture content data has not been included in this report as it is felt that what little variation was detected may have been affected by heavy rainfall during collection of some of the samples (1998 and 1999).

2.1.2 Chemical properties

Sodium content and potassium content both a general trend towards an increase from 1998 to 1999. The exception to this is R2, where both showed a decline from 1998 to 1999.

The data for calcium content are extremely variable. There is a mixture of increases, declines, and no change. The one possibly of note is R2, where a very high 1998 figure has declined quite sharply in 1999.

Table 1: Results of chemical & physical analysis of sediment samples

SODIUM, mg/kg

(Na)		1998	1999	NOTES
Inner	C2	1100	1900	
	C3	590	1400	
	R1	1200	2500	50% rotoburied 09.98
			2500	
	R2	2100	1500	50% rotoburied 04.99
	R3	1600	2900	rotoburied 04.99
Outer	C7	1400	2000	
	C8	1500	2500	
	R7	1500	2100	rotoburied 09.98
	R8	1600	2100	rotoburied 09.98
	R9	1600	2200	rotoburied 04.99
			2600	
Hand pull	Inner		1400	
			1900	
	Outer		2400	
			2500	

CALCIUM, mg/kg

(Ca)		1998	1999
Inner	C2	90	77
	C3	110	85
	R1	120	140
			160
	R2	340	96
	R3	200	190
Outer	C7	170	150
	C8	140	160
	R7	150	160
	R8	170	130
	R9	140	140
			160
Hand pull	Inner		75
			85
	Outer		130
			160

PHOSPHATE/PHOSPHORUS, mg/kg

(PO_4/P)		1998	1999	NOTES
Inner	C2	0.11	0.44	
	C3	0.10	0.18	
	R1	0.11	0.29	50% rotoburied 09.98
			0.23	
	R2	0.06	0.19	50% rotoburied 04.99
	R3	0.08	0.17	rotoburied 04.99
Outer	C7	0.06	0.15	
	C8	0.08	0.18	
	R7	0.08	0.05	rotoburied 09.98
	R8	0.06	0.15	rotoburied 09.98
	R9	0.07	0.12	rotoburied 04.99
			0.15	
Hand pull	Inner		0.08	
			0.16	
	Outer		0.14	
			0.19	

POTASSIUM, mg/kg

(K)		1998	1999
Inner	C2	76	98
	C3	69	88
	R1	78	140
			140
	R2	120	99
	R3	90	170
Outer	C7	83	120
	C8	79	130
	R7	85	120
	R8	88	110
	R9	85	110
			140
Hand pull	Inner		87
			110
	Outer		130
			130

Table 1 (continued)

CADMIUM, µg/g

(Cd)		1998	1999	NOTES
Inner	C2	0.15	0.13	
	C3	0.15	0.13	
	R1	0.11	0.13	50% rotoburied 09.98
			0.10	
	R2	0.15	0.13	50% rotoburied 04.99
	R3	0.14	0.15	rotoburied 04.99
Outer	C7	0.13	0.11	
	C8	0.09	0.11	
	R7	0.11	0.12	rotoburied 09.98
	R8	0.11	0.11	rotoburied 09.98
	R9	0.11	0.10	rotoburied 04.99
			0.11	
Hand pull	Inner		0.12	
			0.12	
	Outer		0.11	
			0.05	

COPPER, µg/g

(Cu)		1998	1999
Inner	C2	7.2	5.6
	C3	7.4	5.5
	R1	8.3	5.3
			5.8
	R2	9.5	5.7
	R3	5.9	7.3
Outer	C7	4.6	4.6
	C8	3.7	3.8
	R7	5.0	5.0
	R8	4.5	4.0
	R9	4.1	3.9
			3.8
Hand pull	Inner		5.0
			6.0
	Outer		3.7
			4.8

ZINC, µg/g

(Zn)		1998	1999	NOTES
Inner	C2	49	40	
	C3	47	39	
	R1	52	39	50% rotoburied 09.98
			40	
	R2	57	40	50% rotoburied 04.99
	R3	42	45	rotoburied 04.99
Outer	C7	38	37	
	C8	34	32	
	R7	40	38	rotoburied 09.98
	R8	36	33	rotoburied 09.98
	R9	34	32	rotoburied 04.99
			32	
Hand pull	Inner		37	
			40	
	Outer		31	
			34	

LEAD, µg/g

(Pb)		1998	1999
Inner	C2	20	18
	C3	22	17
	R1	23	17
			21
	R2	28	17
	R3	19	20
Outer	C7	15	15
	C8	15	14
	R7	16	16
	R8	15	13
	R9	15	14
			14
Hand pull	Inner		15
			18
	Outer		12
			15

Table 1 (continued)

LOSS ON IGNITION, %

(LOI)		1998	1999	NOTES
Inner	C2	2.2	2.1	
	C3	1.7	1.9	
	R1	2.0	2.1	50% rotoburied 09.98
			2.1	
	R2	2.4	1.9	50% rotoburied 04.99
	R3	1.9	2.6	rotoburied 04.99
Outer	C7	1.6	1.8	
	C8	1.4	1.7	
	R7	1.7	1.8	rotoburied 09.98
	R8	1.5	1.6	rotoburied 09.98
	R9	1.5	1.5	rotoburied 04.99
			1.7	
Hand pull	Inner		1.4	
			2.0	
	Outer		1.4	
			1.8	

TOTAL NITROGEN, %

(N)		1998	1999
Inner	C2	0.029	0.031
	C3	0.037	0.029
	R1	0.037	0.034
			0.031
	R2	0.044	0.030
	R3	0.023	0.051
Outer	C7	0.019	0.022
	C8	0.013	0.020
	R7	0.019	0.024
	R8	0.021	0.021
	R9	0.012	0.018
			0.018
Hand pull	Inner		0.028
			0.040
	Outer		0.021
			0.025

SILT, %

		1998	1999	NOTES
Inner	C2	5.2	5.2	
	C3	8.2	3.2	
	R1	7.2	5.2	50% rotoburied 09.98
			3.2	
	R2	9.2	2.5	50% rotoburied 04.99
	R3	3.2	5.5	rotoburied 04.99
Outer	C7	3.2	1.5	
	C8	2.2	0.5	
	R7	3.2	<0.5	rotoburied 09.98
	R8	3.2	<0.5	rotoburied 09.98
	R9	1.2	<0.5	rotoburied 04.99
			<0.5	
Hand pull	Inner		5.2	
			5.2	
	Outer		1.2	
			2.2	

CLAY, %

		1998	1999
Inner	C2	2.9	1.9
	C3	3.9	1.9
	R1	3.9	1.9
			2.9
	R2	5.9	1.9
	R3	2.9	3.9
Outer	C7	0.9	1.9
	C8	0.9	1.9
	R7	0.9	3.9
	R8	0.9	3.9
	R9	0.9	3.9
			3.9
Hand pull	Inner		1.5
			1.5
	Outer		1.5
			1.5

FINE SAND - range of values (approximate) (by extrapolation – see text)

1998 Inner plots	85% to 94%
1998 Outer plots	95% to 98%
1999 Inner plots	90% to 95%
1999 Outer plots	95% to 98%

Phosphorus and phosphate content showed a general trend towards an increase from 1998 to 1999 (but please see important points made in section **3.1**).

The data for total nitrogen content are rather variable. The proportion of nitrogen tended to be higher in the inner plots. Values remained more or less the same 1998 to 1999, with the exception of R2 (loss) and R3 (gain).

Cadmium content shows little variation between plots or between years.

Copper content of the outer plots remained about the same from 1998 to 1999. The inner plots showed a slight decline over the same period, with the exception of R3, where there was an increase.

The data for zinc and lead content show similar patterns to those for copper, though in R3 the zinc and lead increases are only slight.

2.2 Plant cover

The results of the plant cover recording are set out in **Table 2**. This includes all of the plots where it was possible to make records in both 1998 and 1999.

In April 1998 there was a moderately dense cover of Spartina along the inshore area, with the coverage generally more open towards the seaward parts of the inner plots. Spartina clumps were scattered and relatively infrequent in the outer plots. Some of the outer plot records were of small plants which had been partially buried by sediment movements.

In May 1999 Spartina cover along the inner plots was generally rather dense. Common Saltmarsh-grass *Puccinellia maritima* had also become well-established in some places. Cover in the outer plots remained scattered, but Spartina was now recorded at a greater frequency than in 1998.

The exception to the above was the plots which had been treated, either by rotoburying or by manual labour. A few small Spartina plants had reappeared in some of the rotoburied plots, though some samples had no Spartina at all. The Hand pull sample areas had no Spartina.

The whole of the sample area was subject to visual examination at various times later in the year.

Table 2 PLANT COVER 1998 – 1999
in random 10m x 10m sample quadrats

		April 1998	May 1999	NOTES
Inner	C1	Spartina 1% (17 clumps); Enteromorpha 1%	Spartina 60%; Puccinellia 10%; Algae 5%	
	C2	Spartina 1% (3 clumps)	Spartina 20% (4 large & 15 small clumps); Enteromorpha trace	
	C3	Spartina 1% (6 clumps)	Spartina 5% (12 clumps); Puccinellia 1 plant: Enteromorpha in pools; algal film	
	C4	Spartina 2%	Spartina 40%; Puccinellia 5% (4 large patches); algal film	
	C5	Spartina 15%; Enteromorpha 1%	Spartina 60%; Puccinellia 3%; algal film	
	R1	Spartina 5%	Spartina 2 plants –1 re-growth & 1 seedling – others & Puccinellia outside	50% rotoburied 09.98
	R2	Spartina 15% (many clumps, including re-growth)	Spartina 20 small plants in 5 patches	50% rotoburied 04.99
	R3	Spartina 2% (many clumps, including re-growth)	Spartina trace – 2 small shoots – others away from plot. Enteromorpha in furrows	rotoburied 04.99
	R4	Spartina 5%	Spartina 35%; filamentous algae in pools; algal film	
Outer	C7	Spartina 1% (25 small buried clumps)	Spartina 2% (6 patches with 43 small plants); filamentous algae in pools	
	C8	Nil	Spartina 2 clumps with 26 small plants	
	C9	Green algae trace	Spartina 8 clumps with 35 small plants	
	C10	Nil	Spartina 2 patches in pools – one of 14 plants & the other 35; Puccinellia 1 small plant in Spartina	
	R7	Nil (a few buried plants adjacent)	Nil	rotoburied 09.98
	R8	Spartina trace – 2 tiny buried clumps; Enteromorpha trace	Nil	rotoburied 09.98
	R9	Nil	Sample 1 – Nil; Sample 2 – Spartina 2% (24 small plants in 5 clumps) + Puccinellia 1 small plant in Spartina	rotoburied 04.99
	R10	Spartina 1% (5 buried clumps)	Spartina 8 clumps with 40 small plants	
	R11	Spartina trace – 1 buried clump	Spartina trace – 2 small patches with 8 small plants; Salicornia 1 seedling	
Hand pull	Inner		Sample 1 - Puccinellia 1 patch & Salicornia 2 seedlings; some algal film; Sample 2 - Nil	50% cleared 06-07.98
	Outer		Sample 1 - Puccinellia 1 small plant; Sample 2 – Spartina 1 tiny plant + Puccinellia 1 small tillering plant	Cleared 06-07.98

2.3 Substrate

Sediments were generally noted as of fine sand, sometimes seeming a little "muddy" in the upper few centimetres. A particular feature of many of the sample cores was one or more pale to dark grey bands from 8-10cm downwards. Some sediment cores were dark for much of the lower 15cm, while some others showed mottling. Cores were sometimes found to be wet in the upper layers but dry at depth.

Notes were also taken on surface topography and other physical features. Areas of sediment accretion since the 1998 survey were very obviously present in 1999. A notable area of accretion is the "corner" between the promenade and the promontory of the old baths. In 1998 this area was wet and difficult to walk on. In 1999 the area was drier and firmer underfoot. The sand accumulating here is now onto the edge of the exposed limestone rocks.

2.4 Invertebrates

More records were made of invertebrate traces than of the animals themselves. Faecal pellets and sometimes disused shells of the tiny snail *Hydrobia* occur over much of the surface, particularly in shallow pools and slacks. The surface layers of the "drier" intertidal areas are peppered with the burrow holes of the shrimp-like *Corophium*. Large and small worm burrows were often found at the surface and at depth, with the larger worm burrows probably of ragworm.

Empty and live shells of the tellin group of bivalve molluscs (eg *Macoma*) were found at the surface and within the sediments. Siphon holes of the deeper-dwelling tellin *Scrobicularia* were also found on the surface and within the cores.

Entire or fragments of shore crab carcasses were found here and there. Visits during or just after heavy rain noted the abundance of dead *Corophium* in pools, presumably flooded out of their sub-surface burrows.

Adult flies were seen skimming pools after rainfall. Dry surfaces were sometimes found to have large numbers of what appeared to be collembolans (creatures like springtails). These animals appear to aggregate in subsurface cracks in the sediment, usually quite close to the sea wall. The UEL students found several examples of what were thought to be the larvae of fly species.

2.5 Birds

Groups of shelduck were frequently seen in and adjacent to the outer plots. Redshank and oystercatcher were seen occasionally. The "best time" for waders appears to be on an incoming tide, when redshank and sometimes others follow the edge of the wave front across the flats. Obviously there was some attempt to ensure that the survey visits did not coincide with incoming tides! A favoured area for shorebirds seems to be from near the signal box to close to and around the edges of Blawith Point.

Mallard were sometimes seen in the inner plots, as well as jackdaw, carrion crow and gulls. Of some interest was the presence on one occasion of several collared dove in plot R3, where the birds were pecking at bits of partially buried plant material.

A rather feeble grey goose was present in and between the inner plots during the 1998 sampling. It was thought to be a pink-footed goose from the collection on the duck pond.

A local person, Tony Benson, has daily observed and recorded bird activity on the Grange shoreline over a number of years. Tony feels that bird activity has declined as Spartina growth has become denser, but notes that inshore bird numbers had anyway been declining since the Kent channel moved away from Grange some years ago (see sections **4.3** & **4.4** for description and discussion of this). Tony's recent observations record that waders and wildfowl prefer to forage in the areas without dense Spartina. He suggests that the recently rotoburied area may be favoured because of the disturbance (see section **3.1** for discussion of this).

3. DISCUSSION OF RESULTS 1998-99

3.1 Sediment analysis

The high proportions of fine sand in the sediment samples is in accord with the findings of Anderson (1972). The tendency for finer sediments to gather in embayments is described later in this report. The inner plots have tended to show a decline in silt and clay, and the outers have lost silt but gained clay. This is likely to be related to the ongoing process of sedimentation, also described later in this report.

Loss on ignition is a means of estimating the amount of organic carbon present. Anderson (1972) found LOI values to be within the range 0.6 to 3.72% - the 1998-99 LOI values are from 1.4 to 2.6% (mainly within 1.4 to 2.1%) and are thus in the lower part of the range of values detected in the previous study. Samples taken in future years may find the rotoburied plots showing higher proportions as the buried plant material decomposes and becomes incorporated into the sediments.

Anderson (1972) found nitrogen values within the range 0.001% to 0.054%. Our results range from 0.012 to 0.051% but are mainly within the second and third quartiles of the 1972 range of values, ie not particularly high or low.

LOI and nitrogen were both found by Anderson to show a correlation with finer sediments. Anderson's analytical work estimated median grain size of sediment whereas the 1998-99 work measured the proportion of sediment within each category of the standard classification. The latter method detected the proportions present of the finest sediments (silt and clay) and these have been summed and plotted against loss on ignition and against total nitrogen. As Anderson also found a correlation between LOI and nitrogen these were also plotted against each other.

The results of the calculations are shown in **Figures 2**, **3** & **4**. Each of the three graphs shows a reasonably good linear association between the variables, suggesting a similar pattern is present to that found in the 1972 work.

Anderson (1972) found phosphorus values in the range 0.016 to 0.048%, noting that the maximum values of 0.035-0.048% were found off Grange and Morecambe and were likely to related to sewage input. The 1998-99 samples gave phosphorus values in the range 0.06 to 0.44mg/kg, which is something like three orders of magnitude smaller than detected thirty years earlier. Lest it be thought an error has occurred, the notes on analytical procedures (Woods *et al* 1999) point out that the 1998-99 sample "P-PO_4 concentrations were near the detection limit of 0.02 mg kg^{-1}", ie very low. The reasons for low phosphorus in 1998-99 are not clear. Certainly the construction (1986 to 1991) and implementation of Grange waste water treatment works has reduced the localised input of phosphorus. But this would not account for a decline of such magnitude. One answer might be that the phosphorus is being taken up by the Spartina and other plants present. Establishing this fact would require further investigation.

Figure 2: Loss on ignition vs Nitrogen

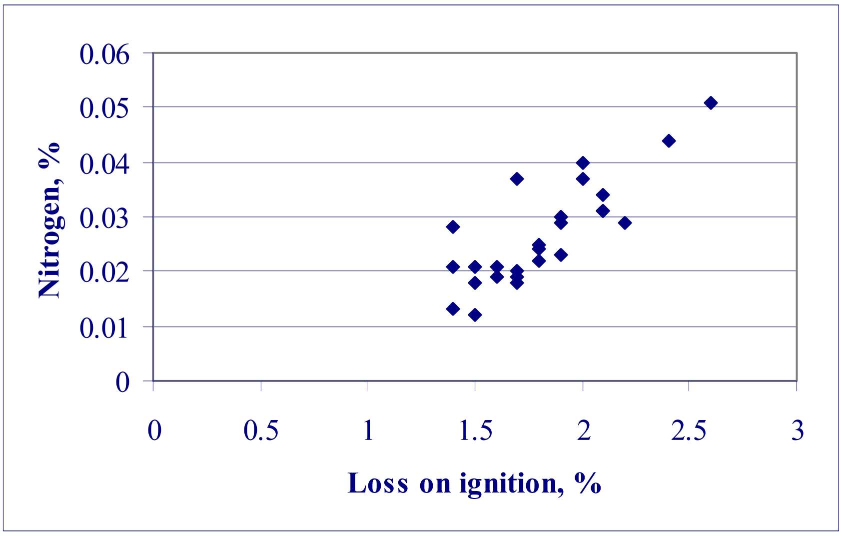


Figure 3: Loss on ignition vs Silt & clay

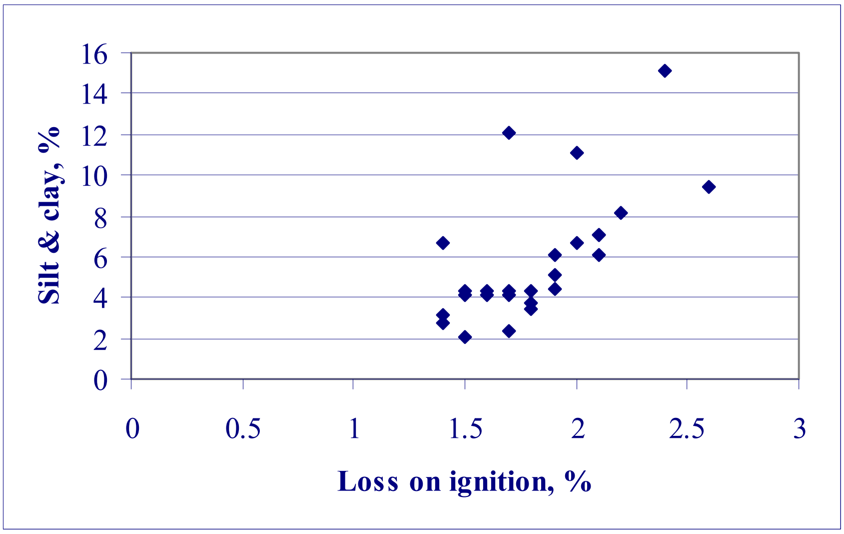
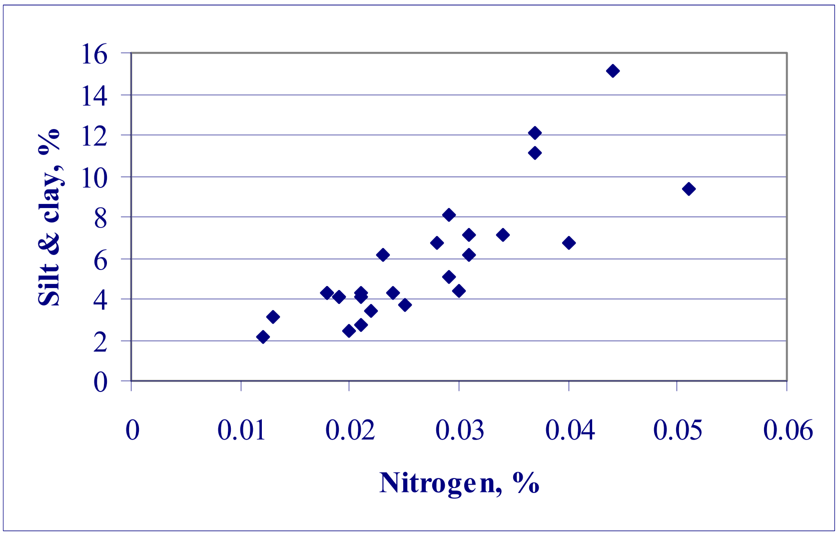


Figure 4: Nitrogen vs Silt & clay



Anderson (1972) found calcium values to be "reasonably constant", and mainly in the range 2.0 to 2.5%. The 1998-99 work found values of 77 to 340mg/kg, with these mainly in the range 140 to 170mg/kg. This is equivalent to mainly in the range 1.4 to 1.7%, with only two samples above 2%. Anderson notes that calcium in the sediments is related to the presence of mollusc shells, particularly those of mussel. She also notes that it tends to be associated with coarse sediments. The 1998-99 work has been in an area of predominantly fine sediments, which would probably explain why the calcium content is low in comparison with the 1972 work. Coarser sediments at Grange would be likely to be found in the areas to the seaward of the study area.

The 1998-99 samples were also analysed for materials not described in the 1972 Anderson paper. Bradley (1997) has analysed the presence of heavy metals along the west Cumbrian coast (St Bees to Drigg) and within the Esk estuary. **Table 3** shows a comparison between the 1998-99 mean values of lead, zinc, copper and cadmium recorded on the Grange foreshore and those recorded at some of Bradley's sites in west Cumbria. It can be seen that the 1998-99 Grange data compares favourably with that from the west Cumbrian sites, with in some cases the west Cumbrian sites showing considerably higher levels.

One of the objectives of the 1998-99 work was to see if the plots rotoburied since 1998 were in any way physically or chemically "different" from plots which had had no treatment. From **Table 1** it can be seen that the sample sets for the various physical and chemical properties show one of four general tendencies from 1998 to 1999:

Proportion generally increased
Proportion generally reduced
Proportion more or less the same
Proportions increased, reduced & more or less the same, ie no trend shown.

These patterns seem to be fairly consistent across both treated and untreated plots. This would seem to suggest that the rotoburying has not provoked any great release of (possibly undesirable) material into the ecosystem as a whole. This is obviously quite important when considering whether to continue with the exercise.

As noted in section **2.1**, there are some exceptions to the trends. The exceptions occur in two of the inner rotoburied plots, R2 and R3.

In 1998 R2 had the highest proportion of total nitrogen recorded in that year's samples. The 1999 data showed declines in total nitrogen and LOI, and also in sodium and potassium. In 1998 R2 also had the highest proportion of calcium: this dropped quite sharply in 1999. In 1998 R2 was by far the "muddiest" of the samples, with silt 9.2% and clay 5.9%, higher proportions than recorded in any other 1998 or 1999 sample. In 1999 the silt content of the R2 sample fell to 2.5% and that of clay to 1.9%. Thus the mud fraction fell from 15.1% to 4.4%, quite a substantial drop.

Table 3 COMPARISON OF HEAVY METAL CONTENT OF COASTAL & ESTUARINE SEDIMENTS

All figures shown are sample means, in µg/g

	LEAD Pb	ZINC Zn	COPPER Cu	CADMIUM Cd
(a) Grange-over-Sands foreshore	15.9	36.4	5.0	0.11
(b) West Cumbrian coast				
St Bees to Drigg	17.4	31.0	5.5	0.01
(c) Active sediments of the Esk channel				
Eskmeals viaduct	38.0	90.4	13.7	0.34
Newbiggin	21.7	42.6	5.0	0.11
Hall Waberthwaite	13.5	46.5	3.6	0.16
(d) Saltmarsh sediment profiles (Esk)				
Newbiggin	57.0	108.6	16.6	0.14
Hall Waberthwaite	54.4	126.5	19.9	0.35

(a) Grange-over-Sands foreshore data from Table 1 of this report

(b), (c) & (d) West Cumbria data from Bradley (1997)

Anderson (1972) suggests that LOI and nitrogen are associated with finer sediments, and this is supported by the findings of the present survey (see above and **Figures 2**, **3** & **4**). It thus seems fairly safe to assume that the decline of nitrogen and organic carbon is related to the relatively abundant loss of silt and clay. We could extend this to suggest that it may also account for the loss of sodium and potassium. Luck might be being pushed were we to suggest this also to be the reason for the loss of calcium, having earlier supported Anderson's statement that the presence of calcium is linked to the presence of coarse sediments – but on paper this looks as though it is what happened. There may be a different explanation which our tests and observations have failed to detect.

Aspects of the data for R3 appear to have behaved in the opposite way to those of R2. The 1999 data gave the highest proportion of total nitrogen recorded in the survey. LOI also showed an increase. Copper, zinc and lead showed a decline from 1998 to 1999 in all the inner plots except R3, where each showed an increase. Similarly, there was a decline in clay and silt in each of the inner plots with the exception of R3, where there was an increase.

So, just as the decline of various items in R2 could be linked to the loss of silt and clay, the increases in R3 can probably be linked to the increase in these finer sediments.

In 1998 R2 and R3 were the only plots with calcium at over 2%. In 1999 R3, as R2, showed a loss of calcium. In R3 this could be linked to the gain of finer sediments, in contrast to what has happened in R2 (see above).

The gains and losses in R2 and R3 would seem to be linked to the inward or outward movement of finer sediments. R2 and R3 were rotoburied at the same time (April 1999) but it seems likely that the changes recorded are related to sedimentation processes rather than as a consequence of rotoburial.

In terms of sediment particle size the broad trend 1998 to 1999 is of a loss of silt from all plots, with clay lost from the inner plots but gained by the outers. This would seem likely to be related to the ongoing process of sedimentation, further discussed in section **4.3** of this report. The other changes in the physical and chemical properties of the samples would appear to be linked to the changes in the component particle size. The occasional apparent bucking of the trends (R2 and particularly R3) fit this hypothesis, as described and discussed in the paragraphs above.

Thus it would seem that the reasonably consistent changes in the physical and chemical nature of the samples (and thus the plots) can be ascribed to sedimentary processes. The process of rotoburial does not appear to have had any adverse impact, at least not within the period of monitoring.

3.2 Plant cover

The plant cover recording described in section **2.2** and set out as **Table 1** are for field work carried out in the middle to late spring period. Spartina growth begins in mid spring, with maximum growth usually reached in late summer, coinciding with flower production. Flowering may continue into the winter months if conditions are mild. Seed set in Spartina is very variable (see, eg, Marks & Truscott 1985), with often very little viable product. In some years, though, seed production may be very high. The reasons for this are not yet fully understood. 1998 seems to have been a "good year" for seed production in the Grange population of Spartina. While the controls of viability are not clear, it does seem likely that the extended mild weather of winter 1998-99 would have given a prolonged period of Spartina flowering, thus increasing the possibility of an abundant yield of seed were it to be viable (which it has proved to be).

Thus the cover of Spartina at Grange has increased from 1998 to 1999 more greatly than might be expected in a normal year of low seed viability. Rotoburied plots inspected in May 1999 were found to be clear of Spartina or virtually so. Inspection again in September 1999 found that there had been some germination from seed on these cleared plots. A spot check of the rotoburied R7 counted forty-seven small plants of Spartina over the entire plot.

Some of the plants present in the inner plots and the landward end of the outers had in September reached a good size. Plants in the outer plots were sometimes at 0.9m height, while some in the inners (eg C1) were at 1.1m. Many of the circular clonal patches in the inner plots had become extensive and sometimes rather dense. It was also noted that clumps of Spartina were now present on the low sandy banks to the seaward of the outer plots.

Common Saltmarsh-grass *Puccinellia maritima* had also become well-established on the sand between and among the patches of Spartina. In 1998 there was an area of more or less continuous cover of *Puccinellia* along the base of the promenade in the area on the north-east of the storm drain creek near the "Commodore" public house (near R5 on **Figure 1**). In 1999 smaller areas of continuous *Puccinellia* were found all along the base of the promenade from the storm creek to the old baths. The areas by the ramp at the baths end had other saltmarsh species such as Sea Aster and Common Scurvy-grass present in spring 1999. Patches of *Puccinellia* were also developing away from the immediate base of the promenade, as noted above. *Puccinellia* is a low-growing rhizomatous perennial grass which spreads vegetatively by an extensive network of creeping shoots (stolons). It is often the major constituent species of the lower and middle parts of an established saltmarsh.

The sediment analysis may suggest that there is an ingress of fine sand to the study area. Certainly the presence of accretion mounds and fans were seen on the shoreward side of patches of Spartina and of *Puccinellia*, particularly in 1999. But 1998 and 1999 surveys both noted also the presence of scour pools around clumps of Spartina, indicating that erosion is also taking place. The relationship of the plants to the processes of erosion and accretion is discussed in section **4** of this report.

Overall, there has been a net gain in vegetation cover in the study area. The gain has been locally controlled by the processes of rotoburying and hand pulling, but this has been slightly offset by the production of a large amount of viable seed from the established Spartina.

3.3 Invertebrates and birds

It is popularly assumed that Spartina is not beneficial to shore birds in that it grows on previously unvegetated areas of intertidal mud and sand and thus occupies what had previously been feeding areas for wildfowl and waders. Goss-Custard & Moser (1988, 1990) suggest that there may be a link between the expansion in Spartina cover and the decline in the numbers of dunlin. However, as these authors point out, there may be third factor at work, and it seems likely that the situation is more complex than had been assumed (see also Gray *et al* 1991).

Local birdwatcher Tony Benson, as noted in section **2.5**, has observed a decline in the numbers of birds using the inshore areas at Grange. Tony comments that the birds that do still forage close to the promenade tend to avoid the areas of denser growth of Spartina. Birds he notes as formerly more abundant include lapwing, mallard, pintail, shelduck, oystercatcher, curlew and redshank. These birds are generally still present but now congregate around the edge of the river channel, now some distance from the promenade. Tony is concerned at what he sees as loss of foraging habitat in the Bay as a whole.

Though Spartina obviously occupies space in the intertidal zone there is evidence that invertebrates are present on the sediment exposed between the clumps and that birds will feed there. We have seen shorebirds (and terrestrial ones) during the course of the present work. Covey & Davies (1989), recording *Hydrobia* at Scarth Bight (just north of Barrow), note that “the snail was often found around the base of the *Spartina* and *Salicornia* plants”. Tittley (1992), at Roosecote Sands, Barrow, comments “the *Spartina* marsh provided habitat for foraging wildfowl and waders: mallard, redshanks, turnstones, oystercatcher and teal were commonly observed”.

Jackson (1985; also Jackson *et al* 1985)) studied a site on the Stour estuary in south-east England, recording the numbers of invertebrates present in the Spartina and also in the unvegetated areas to the seaward. The Stour work found very high numbers of ragworm, *Hydrobia* and *Corophium* to be present in the Spartina area, plus also other species not found in great numbers in Morecambe Bay. The animals mentioned were of course also present in the adjacent mudflats. Jackson did find that the tellin *Macoma*, though present in the Spartina, occurred at a much greater density in the unvegetated zone. The Jackson studies did also record a considerable variety of terrestrial insects, mites and spiders living in and on the leaves and other aerial parts of the Spartina.

The UEL students did attempt to record invertebrates from samples collected immediately adjacent to or within larger clumps of *Spartina*. It is understood that fewer animals were found in these particular samples, though it must be noted that animals smaller than their relatively large sieve size may have been missed. We did also persuade one UEL group to sample from beside and beneath a clump of *Puccinellia* close to the promenade. The drier sand here was tightly packed by the plant root mat and was difficult to penetrate. The results of this have not been passed to us but *in situ* observation suggested the *Puccinellia* sample would be poor in at least the larger invertebrate species.

Our own observations and recording and that of the UEL students indicate that the expected invertebrates are present in and on the sediments of the Spartina areas. Previous work on Morecambe Bay (Anderson 1972) indicates that there is a low diversity of invertebrate species in and on the intertidal sediments but that those that are there are often present in great numbers. Our observations and records concur with those of Anderson for nearshore areas.

The question of longer term availability of feeding areas is discussed in section **4** of this report.

3.1.1 Does rotoburying have any effect on the invertebrates?

Prior to commencement of the project some concern was expressed as to what impacts the rotoburying would have on the invertebrates of the affected areas of sediment.

George et al (1992), *à propos* of proposed pipeline work across the intertidal and subtidal areas near Barrow, list four ways that digging and trenching may affect the invertebrates:

- physical removal of sediments in which they live
- physical burial of sediment at dump sites
- an increase in water turbidity
- release of toxic chemicals previously bound in the sediment

Physical removal and burial would be issues at Grange insofar as the rotoburying churns up and redistributes the sediments on a localised basis, ie within the confines of each plot treated.

An increase in the turbidity of the water may not be an issue at Grange. Anyone who has stood on the promenade on a high spring tide in Grange or Morecambe will have seen that Morecambe Bay waters are already quite turbid.

The question of possibly toxic materials was addressed in the chemical analysis of sediments (see sections **2.1.2** & **3.1** of this report). The lack of separate trends for rotoburied and control plots suggests that the disturbance does not release any undesirable substances into the wider ecosystem here.

Further investigation of the physical disturbance factor led us to consult various papers on the environmental impacts of bait digging. Much of the published work refers to animals not found in Morecambe Bay, or at least not in the inshore areas. Two papers were found to contain material of relevance to the Grange rotoburying trials.

McLusky *et al* (1983) recorded in the holes dug and the resultant mounds of spoil, and in control areas. They found that lugworms were displaced for up to three months. *Hydrobia* and *Macoma* showed enhanced populations on the mounds for up to two weeks but were otherwise unaffected. The holes also acted as sinks for particulate matter such as seaweed debris, and showed initially enhanced levels of nitrogen and organic carbon. It should be noted that lugworms are not found within our study area at Grange.

Van den Heiligenberg (1987), again mainly studying lugworm, also noted that *Macoma* showed a fast return into the disturbed areas.

It seems likely that rotoburial would impact most severely on species which live on or just below the surface, such as *Hydrobia* and *Corophium*. *Hydrobia* is highly mobile and may well be able to make its way back up to the surface. *Corophium* may be less able to cope with burial, but we have noted earlier that there appears to be considerable natural wastage of *Corophium* individuals during periods of heavy rainfall.

Our own recording and observations suggest that invertebrates had “returned” to the rotoburied plots. The UEL 1999 work was carried out some two weeks earlier than our own, and was thus nearer in time to the April 1999 rotoburying. The UEL final results have not been made available to us but observations made at the time suggested that the recently rotoburied plots were considerably richer in invertebrates than had been expected.

McLusky *et al* (1983) and Van den Heiligenberg (1987) both comment on the rapid ingress of mobile species to the disturbed areas, and this would appear to be what happens at Grange. The act of rotoburial will inevitably result in some localised loss of invertebrates, but the disturbance then creates a new niche, which attracts animals from elsewhere. In due course the disturbed plots then return to conditions similar to those present prior to the rotoburial.

It is known that birds are attracted to soil disturbance such as ploughing or even the turning over of beds in the garden. The same is likely to be true of the rotoburied plots on the Grange foreshore, at least in the period immediately following treatment.

4. FURTHER DISCUSSION

4.1 Morecambe Bay processes

The Estuaries Review (Davidson *et al* 1991) classifies Morecambe Bay as an estuary of the "embayment" type, noting that, on a local scale, the various rivers discharging into the large embayment may show characteristics of "coastal plain estuaries".

The Estuaries Review also classifies sites according to the average range of spring tides. Estuaries such as Morecambe Bay, with a maximum range greater than 4m, are considered "macrotidal". The tidal range at Morecambe Bay is in fact one of the largest in Britain, exceeded only by that of the Severn estuary.

Broadly speaking, Morecambe Bay, as classified above and as recognised in international legislation, includes all the area behind a line between the tip of South Walney and Fleetwood. This area includes three estuarine areas designated under UK legislation as a Site of Special Scientific Interest (SSSI). The Morecambe Bay SSSI extends from the tip of Foulney Island across to Heysham Harbour. It is the processes operating within the Morecambe Bay SSSI which mainly concern us here, and any reference to the Bay may generally be taken as referring to that area.

Morecambe Bay is fed by three larger rivers, with the Rivers Leven and Keer being low tide tributaries of the main river, the Kent. A river such as the Mississippi has a significant physical impact on the sea into which it discharges. British rivers operate a considerably smaller scale. In our estuaries the sea is the dominant water body, but at sites such as Morecambe Bay there is still a significant role played by the rivers (see section **4.3** below).

Coastal saltmarshes are areas of vegetation regularly subjected to periods of tidal inundation. Saltmarshes are a characteristic feature of much of the Morecambe Bay shoreline. The marine fraction of estuarine water means that there will be at least some degree of salinity, and saltmarsh plants must be adapted to spending fractions of their life with their aerial parts or roots sitting in salty water.

Saltmarshes may develop where there is an availability of suitable substrate (mud or sand); periods free from tidal inundation (to allow seed to germinate); and a degree of shelter from wave action & currents (to allow young plants to develop a root system to anchor them in place). There must of course also be an availability of one or more species suitable to exploit the conditions.

The size and shape to which a saltmarsh develops is dependent on a variety of factors. The degree of shelter from wave action and current is again a key factor. The shoreline gradient and tidal range are important. A steeply sloping shore has a lower potential area of saltmarsh than one with a gentle undulating gradient (as at Morecambe Bay), and a broad tidal range would again mean a potentially greater area would be available. The cohesive properties of the sediments also play a role, with the saltmarshes on mud developing different topographic features to those on sand. The sediment type may also play a role in the subsequent land use of the marsh.

The traditional view of saltmarsh development is that it may be initiated when intertidal sediments accrete to above the level of mean high water neap tides. The sediment surface may be stabilised by a film of micro-organisms such as diatoms or blue-green algae. The first plants to appear tend to be Glasswort species (*Salicornia*). With some further accretion of sediment the *Salicornia* may be joined by Annual Sea-blite (*Suaeda maritima*) and then Common Saltmarsh-grass (*Puccinellia maritima*). These early stages of saltmarsh development are often referred to as “pioneer”. Where accretion continues, the *Puccinellia* begins to dominate, often being joined by a variety of other species tolerant of the less frequent immersion now experienced. The saltmarsh may accrete sediment to sufficient height above mean neap tide level that plants such as Red Fescue (*Festuca rubra*) and Saltmarsh Rush (*Juncus gerardii*) are able to establish. These higher levels of the saltmarsh may experience inundation by only a small proportion of the higher tides. Strandlines and the landward transitions of saltmarshes develop their own characteristic suite of flora, and swamp and “terrestrial” marsh species may grow where non-saline water permeates the saltmarsh. The various zones of the saltmarsh which develop after the pioneer are often referred to as “low marsh”, “mid marsh” and “upper marsh”. The terms “low-mid” and “mid-upper” are sometimes used for intermediate areas.

Saltmarshes develop a drainage system of creeks, often reflecting the incipient drainage system present at the early stages of plant colonisation. The creek pattern varies according to the nature of the substrate, with a dendritic network characteristic of muddy marshes and a herringbone pattern on sandy ones. Creeks on more mature marshes may become blocked, possibly a reflection of insufficient tidal penetration of the higher areas of the saltmarsh.

The mature saltmarshes of Morecambe Bay are often extensive, but tend to lack the pioneer and low marsh zones. This is related to a number of factors, including the topography of the Bay and the action of fast flowing tides. Gray (1972) suggests that the preponderance of coarser sediments would in this situation result in areas too mobile for the traditional pioneer species to become established. Locally, pioneer and low-marsh zones are found in more sheltered areas such as the shores along the Walney channel, parts of the Lune estuary, and in the estuary of the Wyre.

The generally sandy nature and relatively high altitude of the typical Morecambe Bay saltmarshes makes them particularly suitable for the grazing of stock, especially sheep. This has led to the development of a relatively even sward dominated by low-growing perennial grass species. As noted above, the grass cover usually extends to the seaward edge of the marsh, terminating at a short cliff above the adjacent sandflats.

The tide may enter Morecambe Bay with some considerable force, and has been known to alter the positions of sandbanks “overnight”. This may also result in some realignment of the low tide channels of one or more of the rivers. Over a longer timescale there is evidence that the low tide channels alter their positions in relation to the shore. This is of great significance and is discussed in sections **4.3** and **4.4** below.

The Morecambe Bay saltmarshes and processes relating to them are described in Gray (1972), Gray & Bunce (1972), Gray & Scott (1987) and Adam (1996).

4.2 What is Spartina?

Spartina anglica is a relatively new member of the British flora. Briefly, the plant arose as a fertile strain of a hybrid between a native and a non-native species in the Southampton area at the end of the nineteenth century. The Spartina was found to possess characteristics not present in the parents, being able to grow at lower levels on the shoreline and having more vigorous growth. These characteristics impressed entrepreneurs of the time and the "new" Spartina was extensively planted to assist in the processes of coastal defence and land claim from the intertidal area.

The history of Spartina is reviewed by Gray *et al* (1991). Papers on the ecology and nature conservation impacts of Spartina are included in Doody (1984) and Gray & Benham (1990).

Spartina, as noted above, evolved in southern England, and much of the early planting was along the southern and south-eastern coasts, where colonies became established and spread into adjacent areas with suitable habitat. The first planting recorded for north-west England was on the Ribble in 1932, with apparently natural spread to the Wyre first noted in 1942 (Hubbard & Stebbings 1967). According to Whiteside (1984, 1987) the first Spartina record for Morecambe Bay is at Rampside in 1949. Whiteside lists the first record for the Grange area as being at Humphrey Head in 1967. Gray (1970) suggests that Spartina was seen at Cowpren Point in about 1945, with the plant appearing to the west of Holme Island, Humphrey Head and Sandgate in the early 1960s.

Spartina is able to grow at lower levels on the shore than other saltmarsh plants. It also possesses the ability to become established where there is some sediment mobility, in the fashion, perhaps, of species which stabilise mobile sand dunes. These two facets enable Spartina to colonise areas previously unavailable to higher plants. In the case of Morecambe Bay it means that "suddenly" there is at certain sites the potential for the establishment of pioneer and low-marsh vegetation. Thus, in an accreting estuary *Salicornia* and *Puccinellia* may become established in areas where, without the Spartina, they may not have become established until a much later time, if at all.

Spartina may appear in the vegetation of an "established" low marsh, but only if a suitable niche is available. The most likely sites are areas of bare ground such as within creeks or pans (shallow or deeper basins on the marsh surface). Spartina may grow where existing low marsh vegetation has died through the rotting of green algae washed onto the saltmarsh. Spartina may also appear in the gaps created when the edge of an established saltmarsh has been broken up by wave damage. In these instances the original grassy sward may re-establish itself and give the impression that the Spartina has invaded an undisturbed sward. This may be currently seen at Crook Cottage, Thurnham, on the outer part of the Lune estuary.

Gray et al (1995) have collected data on tidal range and variables such as fetch, estuary area and latitude from British estuaries. From this they have produced a simple model which may be used to estimate the niche range of Spartina at a given site. This model can be used, for example, to predict whether Spartina is likely to occur after alterations to the configuration of a coastline.

The view of Spartina as a "problem" is perhaps indicated by the regular appearance of literature describing attempts at control. Papers such as those by Ranwell & Downing (1960), Truscott (1984), Garnett *et al* (1992) and Bennett (1996) describe attempts at control using chemicals. Davey (1993) mainly describes chemical control but also mentions hand pulling and digging. The article by Davey *et al* (1996) describes the initial rotoburying trials at Lindisfarne, north-east England.

The reasons for control mentioned in the above and other papers include the taking up of the feeding area of water birds and the loss of amenity. Some authors also cite that Spartina reduces botanical diversity, notably Doody (1990), who says it is "replacing a potentially more diverse plant community". The authors would assert that this is certainly not the case in Morecambe Bay or indeed in north-west England, for, as described above, Spartina becomes established at lower levels and on sediments too mobile for other saltmarsh species. It also does not appear to be the case on the variety of East Anglian marshes one of the authors has studied for the last eleven years.

As noted earlier, the earliest establishment of Spartina populations was in southern Britain. These populations tended to be in estuaries with very fine (muddy) sediments. Many of these southern populations of Spartina have, after a period of time, exhibited the phenomenon known as "die-back". The process is still incompletely understood but is thought to be linked to imperfect drainage causing a build up of materials harmful to the plant. The Lancashire and Cumbria populations of Spartina are of more recent origin and there has thus been less time in which to study trends of this nature. The fact that north-west England marshes tend to be on coarser sediments may suggest that the occurrence of die-back may be less likely to occur here. But the estuaries of the north-west also differ in their having a wider tidal range, which, coupled with low gradient and often greater extent, may have their own long-term impacts on Spartina populations. This is further discussed in the sections which follow.

4.3 What is happening on the shore at Grange?

4.3.1 Historic changes

An accreting shoreline has always held an appeal to those eager to increase their holdings, and that of Morecambe Bay has been no exception. Gray & Adam (1974) catalogue the various successful and unsuccessful land claim attempts on and around the Bay. These authors note that the practice goes back to the monks of Furness Abbey in the thirteenth century, with efforts more widespread from the eighteenth century onwards.

Without doubt the most significant act was the construction of the Lancaster to Ulverston railway, completed in 1857. Gray & Adam (1974) note that this allowed the incidental reclaim of about 1 000 acres of land which "changed the outline of the bay more than any other recent event". Area of saltmarsh were enclosed by the railway, including along the Grange shoreline; among these are present day features such as the golf course and the duck pond.

The construction of the railway viaduct between Arnside and Meathop served to fix the river Kent at that point, particularly after further work carried out during the 1914-18 War (Gray & Adam 1974). This, while having localised impacts, still allowed changes in channel alignment in areas both up- and downstream. The fluctuations of the low tide channels in Morecambe Bay are of particular significance and have been researched in some detail.

Gray (1972) produced a set of maps and data (also in Gray & Scott 1987) which show recent historic changes in the alignment of the Kent and Leven channels and the areas of saltmarsh around the Bay at these various times. This work indicates that the Kent channel has shown a tendency to move from the Grange side of the Bay across towards Silverdale and then work its way back again. Saltmarsh development and extension occurs at Silverdale when the channel has been close towards the Grange shore. The periods when the channel moves towards the Silverdale shore see erosion and contraction of its area of saltmarsh. This aspect of the work has been progressively updated by Pringle (1987, 1989, 1995).

An important fact to note is that the intertidal area of Morecambe Bay contains not only the main channels of the rivers Leven, Kent and Keer but also their subsidiaries. These subsidiary channels vary in their size and location. The larger subsidiaries make a significant contribution to the direction of tidal inflows, and thus play an important role in the processes of erosion and accretion.

Returning to the matter of Silverdale to Grange movement of the Kent channel, Gray (1972) indicates that in the latter part of the nineteenth century the channel was towards Grange and an extensive area of saltmarsh was present at Silverdale. The map for 1909-19 indicates that the channel had by then changed its orientation, swinging tightly around Blackstone Point and Park Point and running close to shore at Silverdale, where the area of saltmarsh had become greatly reduced. The 1946-55 map shows the channel now again away from Silverdale, with an increased area of saltmarsh there. The 1967 map shows the situation at the time the paper was compiled, with the Kent channel still towards the Grange side of the Bay and a considerable extent of saltmarsh present at Silverdale.

The 244ha of saltmarsh at Silverdale in 1967 (Gray 1972) was around its maximum extent. The Kent channel remained towards Grange until the early 1970s when it began to move back towards the Silverdale shore (Pringle 1987 *et seq*). The more recent events are described in section **4.3.2** below.

So what was happening at Grange during this time? We have mentioned earlier that the construction of the railway enclosed areas of saltmarsh. Reference to collections of historic photographs (Marsh 1988, Broughton 1990, Garbutt & Marsh 1991) can literally give us a picture of the situation from the turn of the century onwards. A late nineteenth century picture shows no promenade and the channel quite close to the shore. In 1900 there was no promenade at Blawith Point and beneath the railway embankment was a short and steeply sloping beach of pebbles down to the sandflats. A noticeable feature of the old pictures, both before and after construction of the promenade, is that the sandflats are at a considerably lower level than they have been in more recent times. This can be confirmed by the views which include the limestone rocks along the edge of the shore, more exposed then than now.

1910 was a period when the Kent channel was very close to Silverdale shore (see above). The saltmarsh at Silverdale was then only of 40ha. Broughton (1990) has a picture of boats at the pier at Grange and comments “silting of the bay prompted an end to this business, with the last sailing taking place in 1910”. Garbutt & Marsh (1991) have a picture taken in about 1910 showing that there was an incised meander quite close to the Grange shore at this time. Given that we know that the Kent was over at Silverdale this was obviously a subsidiary channel. This is of some considerable significance and is referred in discussions which follow.

Researchers working in Morecambe Bay have little doubt that land claim and particularly the construction of the railway have reduced estuarine capacity and given rise to an accelerated accretion of sediments. Gray & Adam (1974) note that over 2 000 acres of saltmarsh have accreted since 1888 in spite of the land claim of some 3 000 acres. The maps in Gray (1972) suggest that the saltmarsh at Storth (immediately upstream of the Kent viaduct) has developed as a direct consequence of railway construction (at Storth, as at Silverdale, there are periods where the marsh edge erodes). Adam (1996), after more recent work on the Bay, records there is still a trend towards an overall gain in saltmarsh, and re-states the significance of construction of the railway in these ongoing processes. The idea is accepted by people who still earn their living from the Bay, as is shown in a review of changes in the Bay witnessed by Flookburgh fisherman Jack Manning (Manning 1998).

4.3.2 Recent changes

The Kent channel began its movement towards the Silverdale shore in the early 1970s, as noted above. This led to a progressive erosion of the edge of the Silverdale saltmarsh, as shown by Pringle (1995, Figure 2). The map shows the shoreline as at 1990, with the area now reduced to some 40ha, similar to the area Gray (1972) gives for the 1909-1915 erosional phase on the Silverdale shore. Pringle (1995, Figure 13) also shows channel configurations along the Silverdale shoreline between 1985 and 1988. From these it can be seen that the channel sitting just off the edge of the Silverdale saltmarsh is in fact a subsidiary, with the main channel lying a little further offshore.

One of the authors of this report visited the Silverdale saltmarsh in mid-October 1999 and found that, although erosion may be continuing in the central area, at the north end (Far Arnside) the saltmarsh edge appears to be as mapped by Pringle for 1990. A difference is that the (subsidiary) channel is now right at the edge of the marsh and at the moment appears to be eroding downwards rather than laterally.

The erosion of the Silverdale saltmarsh (Park Point to Jenny Brown’s Point) has had a knock-on effect in that there has also been erosion of the marsh around the corner from Jenny Brown’s, ie the northern part of the Warton saltmarsh. That erosion here has not been more extensive may be a result of protection afforded by the slag banks along sections of the edge of Warton marsh.

The recent movements of the Kent channel have presumably been also a factor in the movement of its southern tributary. The main and subsidiary channels of the Keer have realigned to the east, with consequent erosion of saltmarsh edge at Carnforth, Crag Bank and Bolton le Sands.

And so the Kent has moved to the east. This will mean that the initial inrushing scour of the tide will be further away from the Grange shore. The ebb water will have further distance to drain and so its impact will also be lessened. We have described how there has been a trend towards accretion in Morecambe Bay: it follows that the lessening of tidal impacts at Grange should provide a regime more suitable for the persistent accumulation of sediments in the inshore area there.

The movement of currents and tides along a shore is “easiest” when the shoreline is relatively smooth. Natural or man-made promontories along the coast break up the pattern and cause a loss of energy and often a deposition of sediments. This is the principle behind the “fishtail” groynes recently installed at Morecambe. Coastal processes operate at a variety of scales, from global downwards. We can scale down our view of processes from, say, Liverpool Bay down to Morecambe Bay *sensu lato* (Walney to Fleetwood) down to Morecambe Bay *sensu stricto* (Foulney to Heysham Harbour). In preceding sections we have been looking at processes within the last of these, but we could scale down to look simply at the processes happening on the Grange part of the Bay. In the Grange area there are obvious shoreline promontories at Humphrey Head and at Holme Island. But there are also smaller promontories such as Blawith Point (natural) and the swimming pool (man made). On a smaller scale yet we may find that even features such as the various steps, ramps and small outcrops of limestone may have a localised effect on sedimentation patterns. As noted earlier, the likelihood of sediment accumulation will be much greater when the Kent channel is away from the Grange shore. Any tendency towards accretion will be enhanced in the lee of the promontories, varying according to scale and local tidal patterns and conditions.

We have seen how Spartina first appeared at Humphrey Head in the early to mid 1960s (Gray 1970; Whiteside 1984, 1987). Gray (1970) comments that the earliest populations of Spartina established in the Bay remained as apparently stable clumps and small patches and did not increase in extent. Expansion to other locations was slow, with Gray (1970) noting only a few new sites appearing by the end of the 1960s. This is likely to be related to the Kent channel’s being positioned towards Grange and to the presence of stable marshes of relatively high altitude on the eastern side.

The Kent channel started to shift its alignment in the early 1970s and this began to upset the apparent equilibrium. Whiteside (1987) says that scattered Spartina appeared on the east side of Holme Island causeway in 1982, though Gray (1970) has it there some time before that. Spartina was certainly present on the east side of Humphrey Head in 1983, though again Gray (1970) has an earlier date. The populations of Spartina at these two sites gradually expanded and plants spread to other parts of the Grange shore as conditions became more suitable for their establishment.

By August 1988 the Spartina had spread along the causeway to beside Holme Island. The landward part of the marsh here now had *Puccinellia* and Sea Aster (*Aster tripolium*) abundant in among the Spartina. Scattered clumps of Spartina were fairly abundant on the eastern side of Blawith Point. *Puccinellia* was colonising the around the edges of the rocks below Grange signal box, with Spartina scattered on the sand around this. There was also occasional Spartina to the seaward and along the mid-shore to the south-west.

By August 1989 a rich area of saltmarsh had developed around the rocks by the signal box, with Sea-lavender (*Limonium vulgare*) and tall stands of Sea Aster making colourful displays when in flower. Both these are relatively uncommon in Morecambe Bay as they are intolerant of sheep grazing. Some of the clumps of Spartina around this new saltmarsh had expanded. A feature of the areas to the seaward and to the south-east was the relatively high frequency of Glasswort plants (*Salicornia*) across the sand flats, a new feature at Grange and, as described earlier, an indication that the beach here had become relatively stable and undisturbed by tidal scour. Spartina, though abundant between Blawith Point and the causeway, was at this time still relatively infrequent across the station to the baths part of the shore.

In or just before March 1992 a subsidiary channel of the Kent appeared off the end of Holme Island and cut in towards Blawith Point and the shore by the station. The new channel took away tonnes of sediment and destroyed the new and developing areas of saltmarsh (remember that the main channel was over at Silverdale then, as before and as now). The rogue channel also took away the outer parts of the causeway marsh and sliced an angled slope off much of the rest of it. Through the rest of the 1990s this subsidiary channel disappeared and the accretion process rebuilt the sandflats in both these eroded areas.

In the mean time, the Spartina at the eastern side of Humphrey Head was spreading, along the promontory and past Kirkhead to Kents Bank and beyond. Sediment accumulation was certainly taking place. Important geological features, described by Rose & Dunham (1977) and visible in 1985, had been covered with fine sand by the early 1990s. In this sheltered environment of accretion the Spartina readily spread seawards, though the rate of accretion meant that the Spartina soon became invaded by *Puccinellia* and Sea Aster.

Further north-east, at Guides Farm, accretion was again rapid but was more confined to inshore areas, though there has been some expansion seawards since the mid 1990s. Along this part of the shore much of the invading *Puccinellia* has consolidated and largely replaced the Spartina. The same is true for large patches of the marsh off the eastern side of Humphrey Head.

At Holme Island causeway the marsh remaining after the 1991-92 erosion gradually expanded again. Spartina is only dominant in the outer parts of the marsh, being increasingly replaced by *Puccinellia* as you move towards land. Towards the corner where the causeway meets the railway bank the marsh sediments have accreted sufficiently to allow the establishment of the saltmarsh dwarf shrub Sea Purslane (*Atriplex portulacoides*). Though accretion and marsh development have continued in the eastern and central parts of this embayment, Spartina remains scattered along the eastern edge of Blawith Point.

The recent situation in the areas from the station to the swimming pool is as described in our survey report in sections **2.2** and **3.2**. Accretion, as noted, is occurring at a rapid pace, including in areas where there is no vegetation. Obvious levees of sand are being developed along the sides of existing creeks. New build-ups of sand bank are developing their own new creek drainage systems.

Within Morecambe Bay there is general trend towards accretion of sediment. This is balanced, in part at least, by episodes of erosion, which free up large or smaller amounts of sediment that will eventually be deposited elsewhere. At Grange it can be seen that sedimentation is occurring regardless of the presence of the pioneer saltmarsh vegetation. We have noted that clumps of Spartina and other species may also be the source of localised accretion (as low mounds in their lee) and of erosion (as scour pools around the clumps). The scour pool effect may also be seen around the pegs emplaced around our monitoring plots.

A similar phenomenon has been studied on saltmarsh and intertidal areas in the Humber estuary. Brown (1998) notes that the net trend to accretion in the intertidal and low marsh zones at Welwick Marsh is independent of the presence of Spartina, and that both erosion and accretion are occurring within the areas of Spartina vegetation.

Vegetation begins to play a more significant role in accretion where *Puccinellia* becomes properly established. We have no quantitative data but visual assessment confirms assertions made by Gray (1970, 1972) that *Puccinellia maritima* is the driver of the early stages of saltmarsh succession in Morecambe Bay. Examples already mentioned would include the extremely rapid 1988 to 1989 development of species-rich saltmarsh around the limestone at Grange signal box, and the grassy sward at Guides farm and within the Spartina along the eastern edge of Humphrey Head.

4.4 What is likely to happen at Grange?

Historic and current evidence points to an overall trend towards sediment accretion within the intertidal areas of the Bay. This phenomenon is not unique to Morecambe Bay. On the Wash, eastern England, Stoddart *et al* (1987) show that, since initial land claim in Saxon times, each episode of land claim has caused new saltmarsh to form to the seaward, with this new saltmarsh then enclosed and the process starting again.

Truscott (1984) notes that have been many land claim schemes along the southern side of the outer estuary of the Ribble. In the early 1970s a seawall was built around the saltmarsh at Crossens and Marshside, with the present coastal road to Southport then constructed. This led to a similar progradation of the shoreline as had occurred many times at the Wash. Sediments began to accrete and Spartina appeared on the previously unvegetated intertidal flats. The spread of plant cover prompted fears of loss of the amenity beach. Truscott describes a programme of herbiciding and has maps which initially suggested some success. But Spartina continued to spread and *Puccinellia* and other saltmarsh plants appeared.

Bennett (1996) describes how plant cover and bare ground have been monitored in sprayed and unsprayed areas at Southport since 1990. There has been an overall trend towards increased plant cover in both treated and untreated plots. It appears that the herbicide may temporarily reduce vegetation cover on a localised basis, but the cover returns with the continuing regime of accretion. Bennett's discussion in places seems to suggest that an expensive programme of herbicide is a waste of resources in the face of what would seem to be an inevitable progression towards full cover of saltmarsh along the shore.

One of the authors of this report visited the Southport coast on several occasions in 1999. The older areas of the Spartina marsh have a similar appearance to those present at Humphrey Head, Kents Bank and by the causeway at Holme Island, with *Puccinellia* and Sea Aster both abundant and the substrate generally sandy and firm. The inshore areas of the oldest of the "new" marshes at Southport now have continuous swards of *Puccinellia*, and the highest parts of these sites have *Festuca* sward and freshwater and other transition vegetation.

We have earlier indicated that rotoburying appears to be a reasonably successful means of controlling Spartina at Grange. But with the accretion of sediment it is likely that seeds and vegetative parts of Spartina and other plants will be able to re-establish. The rotoburying of Spartina may turn out to be similar to attempts to control rushes in damp fields: it looks as though you have got rid of it but then a load more appears.

It may be felt that, at Grange, as at Southport, attempts to control Spartina are regarded as a waste of resources, particularly in view of the fact that each successive year is likely to bring a larger area requiring treatment.

So what will happen at Grange under a "do nothing" control regime? Inshore areas will quickly develop a continuous cover of *Puccinellia*, as has already started to happen. In the absence of any grazing these areas will become quite species-rich and develop colourful displays of Sea-lavender (July) and Sea Aster (August onwards), as previously appeared by the signal box for a brief period some ten years ago. As noted earlier, saltmarshes of this nature are an uncommon feature within Morecambe Bay. In 1989 freshwater transition species appeared where limestone spring water emerged in the young saltmarsh: these may reappear also. At Kents Bank there has been the recent development of a stand of Common Reed (*Phragmites australis*) and other transition vegetation at the back of the marsh. An increased diversity of flowering plants can only enhance the wildlife value of the shoreline. These new plants will attract insects, including bees and butterflies, and also songbirds. The visual amenity will thus also be enhanced.

There is a tendency for people to be reluctant to accept visual change, be it the natural or the built environment. A recent example from the Morecambe Bay area is given. The clearance of scrub and young trees in the Arnside, Silverdale and Warton areas was undertaken in order to re-create areas of species-rich limestone grassland suitable for rare and declining species of butterfly. Many local people were unhappy with the removal of parts of what they saw as the typically wooded character of their landscape. Much of the tree and scrub cover removed has in fact only been present in the areas since myxomatosis in the 1950s, a fact confirmed by older photographs of sites such as Warton Crag. And indeed countryside management workers have only removed a proportion of the newer wooded cover.

At Silverdale there have been periods when there has been little or no saltmarsh. At other times the saltmarsh there has been very extensive. In times past the lack of saltmarsh allowed fishing vessels to use Silverdale as a port. When the Silverdale saltmarsh was extensive it was used as an amenity resource, and in fact is still thus used with the saltmarsh area greatly reduced.

The development of continuous saltmarsh at Grange is probably inevitable. Some Grange people have been quoted in the *Westmorland Gazette* as saying they do not want a "green beach" – why not? As noted above, development of saltmarsh will increase the diversity of plants and animals in the area. As the saltmarsh develops it will become "higher and drier" and provide a readily accessible area for amenity use, certainly one more suitable than the wet and often soft sand of recent years. People use the saltmarsh for amenity and recreation at Silverdale and from Carnforth down to Hest Bank: surely so in future years at Grange?

A continuous area of well-developed saltmarsh would be inundated only by the higher spring tides and would thus provide protection for the promenade. Such a saltmarsh would also provide valuable high tide roost areas for wading birds, as at Carnforth to Hest Bank and elsewhere.

On the subject of birds, there has been some concern that the development of saltmarsh would take up intertidal feeding areas. At Grange accretion is taking place offshore as well as inshore. Invertebrate populations presently in the inshore areas will relocate in other suitable habitat. Correspondence with John Wilson (till recently RSPB Leighton Moss & Morecambe Bay chief warden) has indicated that the movement of the Kent channel towards Silverdale has resulted in a loss of "mid tide" feeding and roost area in that part of the Bay. These areas will re-form in the other parts of the Bay, in the lee of the moving channel. As previously noted, the sediments freed up by erosion events in one part of the Bay are not lost, being re-deposited in other locations.

Various organisations co-ordinate what is now known as the Wetland Bird Survey (WeBS), which on estuaries is based on counts at high tide roosts (Cranswick *et al* 1999). Though important in themselves, roost sites are usually of secondary importance to the manner in which the birds make use of a site for feeding. The WeBS low tide count scheme, initiated in 1992-93, aims to assess and regularly update information on intertidal feeding areas. Low tide counts are at present carried out on twenty-four estuaries. Morecambe Bay is to be added to this list. Low tide counts on Morecambe Bay will give valuable data on the impacts of estuarine processes on the patterns of bird feeding. That this work has not been undertaken sooner is at least partly due to the problems of co-ordinating such a large-scale operation.

We have mentioned earlier that the results of recent surveys (Adam 1996) stated there is still a net gain in saltmarsh in Morecambe Bay. Adam notes that this would be at the expense of intertidal flats, ie bird feeding areas. But there remains a enormous area of intertidal flats in the Bay, vastly greater than the area of saltmarsh. Much of this intertidal area is too unstable and too frequently immersed for the establishment of saltmarsh.

Hale (1984) suggests that many wader populations would have been at their peak during the height of the last period of glaciation. At this time the favoured tundra habitat would have been widespread in Europe and the former Soviet Union. British estuaries would not have been present and so these large numbers of birds would have wintered in Africa and perhaps southern Europe. Hale suggests that the present winter populations are probably well below the carrying capacity of the total estuary stock available. This idea is perhaps a little controversial; it was raised again by Batty (1997) as part of one of the papers at a conference on wetland birds and habitat loss (Goss-Custard *et al* 1997).

Retuning to subject of saltmarsh development at Grange, someone may say so why did saltmarsh not develop the previous time the channel moved over to the Silverdale side of the Bay? Certainly saltmarsh was present in the area when the railway was constructed, as noted in section **4.3.1**. In 1909-15, when the Kent was over at Silverdale, the shore at Grange, while accreting, had probably not yet reached sufficient height for the establishment of saltmarsh plants. The lower altitude of the beach can be seen in the photographs referred to in section **4.3.1**, where there is also reference to a 1910 picture of subsidiary channel lying close inshore. The tidal scour related to this channel would have ensured that *Salicornia* etc would have been unable to establish. Spartina, of course, was not present in north-west England at that time.

Why did the beach at Grange in 1989 develop a cover of *Salicornia*, with Spartina only scattered? Why has it taken till now for continuous Spartina cover to reach Grange? Gray (1970) notes that the original Morecambe Bay Spartina populations initially did not expand or spread elsewhere. As conditions became more suitable expansion of Spartina occurred in the sheltered "ends" of the Grange shore, at Humphrey Head and by the Holme Island causeway. The failure of the Holme Island causeway Spartina to establish on the eastern side of Blawith Point may suggest this is a "less strong" population. It is postulated that the Spartina expansion now present between the baths and the station is derived from what may be the "stronger" population which has spread from Humphrey Head. In 1989 the Humphrey Head-Kents Bank Spartina was "too far away" for viable seed to reach the shore below Grange promenade.

The spread of Spartina in Morecambe Bay appears to restricted by the availability of suitable sediment and by the tendency to produce only small amounts of viable seed. The spread of local patches may be by vegetative means, but it would seem even this is limited when conditions are unfavourable.

Returning to the 1989 developing saltmarsh, it was described in section **4.3.2** how this was largely destroyed in winter 1991-92 by the sudden appearance of a subsidiary channel of the Kent. The intertidal areas and vegetation have re-developed since then. There remains the possibility that such an event could reoccur and remove the present or future expanse of Spartina and saltmarsh.

In the longer term the main channel of the Kent will move away from the Silverdale shore and return to the Grange side of the Bay. Saltmarsh development and expansion will once again take place at Silverdale. Much or perhaps all of the saltmarsh on the Grange shore will be eroded away. This will repeat the cycle of processes described and mapped in Gray (1972) and Pringle (1995). Quite when this will happen cannot as yet be accurately predicted. Perhaps the townspeople of Grange will then be expressing dismay at the loss of their saltmarsh amenity?

At least at Grange we can be sure that the Kent channel and its subsidiaries will one day move back towards the Grange shore and erode at least some of the saltmarsh and accreted sediments. This is unlikely to happen in the case of the new saltmarshes described at Southport (see above), for the channel of the Ribble has long been fixed to run along the Lytham shore, some four to five kilometres to the north.

4.4.1 The Winster

We cannot close without some reference to the river Winster. This was canalised with the building of the railway (Gray & Adam 1974). The intertidal section was trained in the 1970s to allow for a more direct flow into the low tide channel of the river Kent.

There has been for some years now a feeling in Grange that the engineering of the intertidal stretch of the Winster has had a knock on effect on the shoreline along the promenade at Grange. The following are extracted from various issues of the *Westmorland Gazette*:

> In September 1989 a councillor requested that a letter be written to the river authority to ask its views on diverting the (Winster) channel towards Grange, saying "I can recall when there was a watercourse down the side of the promenade" and that "we didn't suffer from Spartina then".
>
> In October 1989 the same councillor felt that "if the river was left to run along this side of the coast there would be no problem with sewerage, high sand banks and Spartina grass". The council chairman is quoted as saying that the 1973 training walls had "caused the build-up of grass at the river's mouth"
>
> In December 1989 the council was addressed by Rob Williams of the National Rivers Authority (NRA, now part of the Environment Agency). He said that diverting the Winster would not help clear the (Spartina) grass, and that even if successful, the diverted river would not have enough energy to scour the coast. He also said there would not be (coastal) scour until the Kent came back to the Grange side.
>
> Moving on to February 1998 it is noted that the majority at a meeting were convinced that the rapid spread of the (Spartina) grass was because of the combined effects of engineering works which have affected the Winster and Kent channels, leading to a build-up of nutrient deposits on Grange foreshore. The Town Clerk was quoted as saying that the "Winster outfall channel groyne and breakwater must be removed at the earliest opportunity".

The same meeting was attended by Flookburgh fisherman Jack Manning, prompting his writing an extensive series of comments and observations to the newspaper (Manning 1998, see later in this section).

English Nature and the Environment Agency eventually consented to a trial removal of the Winster training walls. This was to be carried out in stages, with the initial removal of sixty metres. The impacts (if any) would be monitored and there was provision for cutback of a further hundred metres and then additional increments of twenty metres. The removal of the initial 60m was undertaken in late 1998.

One of the authors of this report visited Meathop saltmarsh and the Winster outfall in early February 1999. The initial cutback of the training wall was not long in having an impact. Incoming tidal water had formed a new subsidiary channel of the Kent. This had heaved into the mature saltmarsh on the eastern side of the Winster, removing a considerable amount of saltmarsh turf and sediment and also intertidal sand. In February 1999 it was possible to stand in the channel and be completely below the level of the remaining saltmarsh surface.

Erosion of the existing Meathop saltmarsh is presumably not what was expected to occur. Apart from its intrinsic ecological and physiographic importance, the saltmarsh at Meathop provides valuable high tide roosting areas for waders and other shore birds, a fact confirmed in correspondence with John Wilson of the RSPB.

An article in the *Westmorland Gazette* the same week as the site visit stated that the shortening of the wall had “already had an effect” (though this effect was not described). The article also notes that the Town Clerk told councillors that the initial cutback had already had “very encouraging results”. It is not clear what is meant by this statement. Certainly no effect was or is apparent along the shore at Grange promenade.

Jack Manning’s letter to the *Westmorland Gazette* a year earlier (Manning 1998) expresses doubt that that the training of the Winster outfall has anything to do with the movement of the Kent channel away from Grange. He points out that the channel movement actually began before the training wall was constructed (this is confirmed by the work of Pringle 1995, as described earlier in this report). Jack says that it was in fact a channel of the Kent which ran close to the shore. He describes how up till 1965 this subsidiary channel ran along the shore to Kirkhead, thence across to Humphrey Head, running alongside the limestone promontory to join the main channel “ a few hundred yards south”. This can be confirmed by reference to the last few editions of the Ordnance Survey (OS) Pathfinder map of the area – the OS has always been a little slow to map changes in the intertidal area!

So it was the Kent, or at least a subsidiary of it, which flowed inshore at Grange, not the Winster. This information has been put into print by a regular user of the intertidal area (Manning 1998) and was also readily available on OS maps. It is perhaps surprising that there has been such apparent pressure to “move the Winster back to Grange” when it would never have been there, at least not since construction of the railway in 1857.

We note above the comments by the NRA that the Winster would not carry the water to have an impact and that it was the Kent which would carry out any scour. Manning (1998) points out that Holme Island extends at least as far as does the Winster training wall.

The removal of part of the Winster training wall has not had the impact that was expected by Grange councillors. It has resulted in an unacceptable level of damage to an area where no impact was intended. In the light of this it seems highly unlikely that the statutory authorities would permit any further cutback of the training wall. In fact it may be considered necessary to reinstate at least part of the training wall, in order to prevent further damage to the existing mature saltmarsh.

4.5 Some concluding remarks & matters arising

4.5.1 What is the role is played by the early colonising vegetation?

Some doubts must be cast on the perceived role of Spartina as a “pioneer” builder of saltmarsh, other than its ability to stabilise sediments too mobile for colonisation by other species. There must also be doubts cast on the role of *Salicornia* and *Suaeda maritima* as pioneer marsh builders. *Salicornia* and *Suaeda* colonise bare areas temporarily free of disturbance, rather in the manner of weeds. They may be in an area where disturbance (eg channel movement) will return and destroy their habitat; or they may be the first arrivals on a patch where accretion will happen regardless of their presence. The invasion of *Salicornia* and *Suaeda* by *Puccinellia* may then accelerate the accretion process, as described in earlier sections.

The above is certainly the case on Morecambe Bay and on the similarly sandy marshes typical of Cumbria, Lancashire and other western areas of Britain. On sheltered muddy marshes *Salicornia* and *Suaeda* may play a role in stabilising mud mounds and flats, areas by nature less mobile than their analogues in a sandy environment.

There is a need for investigations similar to those of Brown (1998) to be carried out at sites at Morecambe Bay and indeed at sites all around the British coast. This work would investigate the true role of different plant species in the accretion and erosion of sediments in the pioneer and low saltmarsh and on the adjacent tidal flats. Many of the original ideas on terrestrial vegetation processes have since been revised and there may be a need for a similar revision of the traditional ideas about the roles of intertidal vegetation.

4.5.2 Where are our experimental plots?

The thickening cover of Spartina along the inshore areas at Grange has made it increasingly difficult to locate the trial plots. A global positioning system (GPS) is a device which uses space technology to locate a ground position. An initial experiment was carried out using the ITE hand-held GPS. The Penrith office of the Environment Agency has a back-pack GPS which gives higher levels of accuracy than the hand-held model. The Environment Agency has agreed to co-operate in the accurate mapping of the trial plots at Grange. This would enable the production of a completely accurate map of the experimental area and would also assist in finding the plots when cover is dense.

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